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## **Long-term clinical results of chairside Cerec CAD/CAM inlays and onlays: a case series**

Otto, T ; Schneider, D

**Abstract:** **PURPOSE:** The objective of this follow-up study was to examine the performance of Cerec inlays and onlays, all of which were placed by the same clinician, in terms of clinical quality over a functional period of 15 years. **MATERIALS AND METHODS:** Of 200 Cerec inlays and onlays placed consecutively in a private practice by one of the authors (TO) between 1989 and early 1991, 187 were closely monitored over a period of 15 years. All ceramic inlays and onlays had been placed chairside using the Cerec 1 method and had been luted with a bonding composite. Up to 17 years after their placement, a follow-up assessment was conducted, and the restorations were classified using modified United States Public Health Service criteria. **RESULTS:** According to Kaplan-Meier analysis, the success rate of Cerec inlays and onlays was 88.7% after 17 years. A total of 21 failures (11%) were found in 17 patients. Of these failures, 76% were attributed to ceramic fractures (62%) or tooth fractures (14%). The reasons for the remaining failures were caries (19%) and endodontic problems (5%). Restorations of premolars presented a lower failure risk than those of molars. **CONCLUSION:** The survival rate probability of 88.7% after up to 17 years of clinical service for Cerec computer-aided design/computer-assisted machining restorations made of Vita Mk I feldspathic ceramic is regarded as a very respectable clinical outcome.

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# **Clinical Results from a Long Term Case Series using Chairside CEREC CAD-CAM Inlays and Onlays**

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## **Abstract**

**Purpose:** The objective of this follow-up study was to examine the performance of Cerec inlays and onlays in terms of clinical quality over a functional period of 15 years which were placed by one clinician.

**Material and Methods:** Out of 200 Cerec inlays and onlays placed consecutively in a private practice, by one of the authors (TO), between 1989 and early 1991, 187 restorations were closely monitored over a period of 15 years. All ceramic inlays and onlays had been placed at the chairside using the Cerec-1 method and had been luted with a bonding composite. Up to 17 years after their placement, a follow-up assessment was conducted and the restorations were classified as per modified USPHS criteria.

**Results:** According to the Kaplan-Meier analysis, the success rate of Cerec inlays and onlays dropped to 88.7% after 17 years. A total of 21 (11%) failures were found in 17 patients. Of these failures, 76% were caused by either ceramic fractures (62%) or tooth fractures (14%). The reason, for the remaining failures were caries (19%) and endodontic problems (5%). Restorations in premolars presented a lower failure risk than in molars.

**Conclusion:** The survival rate probability of 88.7% after up to 17 years of clinical service for Cerec CAD/CAM restorations made of Vita Mark I feldspathic ceramic is regarded as a very respectable clinical outcome.

## **Key words**

Ceramic restorations, CAD/CAM, Cerec, survival rate, long-term results

## Introduction

The rapid development of digital computer technology in the early 1980's led to research into related applications in dentistry. The aim was to provide dentists in private offices with the possibility to independently design and also machine dental ceramic restorations in an efficient and easy manner. As a result of this, 1985 the Cerec system<sup>1</sup> was introduced by Drs. W.H. Mörmann and M. Brandestini at the University of Zurich (Switzerland). In the Cerec system, an optical impression of a tooth preparation is taken with a small opto-electronic video camera and subsequently saved on a chip. The digital 3D-information is transmitted to a computer and the dentist interactively designs the restoration on the screen (Computer Aided Design). These data are used for the form-grinding of an industrially pre-fabricated feldspathic ceramic block with a diamond-coated disc incorporated in a three-axis milling unit (Computer Aided Machining)<sup>2</sup>. In 1986, a major company of dental products (Siemens Dental, now Sirona Dental Systems, Bensheim, Germany) started developing the system further. In 1987, field studies were conducted in selected dental offices<sup>3</sup> and in the end of 1988 the Cerec 1 system was introduced to the market on a broad basis. Since at that time, long-term clinical studies were lacking not only for CAD-CAM ceramic restorations, but also for the adhesive seating of these ceramic restorations, it was decided, to make a follow-up study on Cerec reconstructions placed in our private practice and to check the treatment results in regular intervals. 200 Cerec inlays and onlays, produced in a continuous sequence in our practice were checked after two<sup>4</sup>, five<sup>5</sup> and ten years<sup>6</sup>. The objective of the present study was to examine the clinical treatment results with Cerec inlays and onlays after a 15-year functional period.

## **Material and Methods**

### **Patients, Indications**

Between May 1989 and March 1991, a total of 200 Cerec inlays and onlays were placed in 108 patients (62 women, 46 men) consecutively. The mean age of the patients was 37 years (range 17 to 75 years). Because all patients of the private practice were trained in an initial oral hygiene program, the Cerec restoration group, presented with good dental care and a low risk for caries and were integrated into a regular dental hygiene recall scheme. The patients wished an esthetic restoration without the use of amalgam. The reason to chose the Cerec method was the possibility to have ceramic inlay or onlay produced and inserted in one appointment, without physical impression-taking or having to wear a temporary restoration.

Out of the total of 200 inlays and onlays that were placed, 85 (43%) were 3-surface, 67 (34%) 2-surface, 23 (12%) 1-surface inlays, 14 (7%) were multi-surface inlays with buccal or oral extensions, 8 (4%) were onlays with one cusp and 3 (1.5%) were onlays with two cusps to be replaced. The multi-surface inlays and all onlays were pooled and classified as a 4-surface group (25, 13%). The inlays and onlays were placed in 54 (27%) maxillary molars and 68 (34%) mandibular molars, as well as in 55 (28%) maxillary premolars and 22 (11%) mandibular premolars. One inlay was used to reconstruct a maxillary canine tooth (Table 1).

The mean functional life of the inlays and onlays was 15 years and 8 months, ranging from 14 years 6 months up to 16 years 11 months.

## Restorative Treatment

According to the instructions in the Cerec manual, the cavities were prepared using a 80  $\mu\text{m}$  diamond and were finished with a 25  $\mu\text{m}$  diamond (Intensiv, Grancia, Switzerland). All Cerec inlays and onlays, were carried out by the same operator (T.O.). All cavities were treated strictly using a rubber dam (Ivory, Heraeus-Kulzer, Germany) ; for the base, a glass-ionomer cement (77% Ketac-Bond, 3MEspe, Seefeld, Germany; 23% Vitre-Bond, 3M, St.Paul, MN, USA) was used. The areas near the pulp were treated beforehand with the localized application of a calcium hydroxide liner (Life, KerrHawe, Bioggio, Switzerland). All inlays and onlays were machined using the Cerec 1 hardware (Siemens, now Sirona, Bensheim, Germany) with a hydro-drive and the first software generation COS 1.0. Feldspathic ceramic blocks (Vita Cerec Mk I, Vita Zahnfabrik, Bad Säckingen, Germany) were used exclusively. These ceramic restorations were etched with a 4.9% hydrofluoric acid (Cerec-Etch, Vita). Because silanization of the etched ceramic was added to the protocol of the Cerec manual, 86% of the inlays and onlays were silanized before placement (Silicoup, Heraeus-Kulzer). For the enamel etching, 35% phosphoric acid (Scotchgel, 3M) was used. Enamel etching was reduced from initially 40 s of the first 17% of the inlays and onlays to 20 s, to avoid post-treatment discomfort. A layer of a bonding agent (Cerec-Bond, Heraeus-Kulzer) was applied to the cavities, and the inlays and onlays were subsequently placed with luting composite (Cerec Duo-Cement, Heraeus-Kulzer). In order to avoid overfilled margins, transparent matrices (Universal Contouring Strip, Dentsply-DeTrey, Konstanz, Germany; Lucifix, KerrHawe) were fixed interdentally with wooden wedges (KerrHawe). For the curing of the luting composite, a polymerization light, which was tested routinely with a light meter, was used 3 to 5 times for 20 sec every time (Epilar II, 3MEspe). The occlusion was designed and finished with 40  $\mu\text{m}$  and 15  $\mu\text{m}$  diamond

burs (Composhape, Intensiv). The proximal surfaces were finished with corresponding diamond-coated mechanical interdental files (Proxoshape, Intensiv) and were polished using flexible discs in four steps (Sof-Lex, 3M) as well as interdental polishing strips (3M). Finally a topical fluoride (Elmex-Fluid, Gaba, Basel, Switzerland) was applied to the treated tooth surface.

### **Clinical Evaluation**

The base-line examination of the inlays and onlays, had been carried out by the author (T.O.). After clinical service times of up to 17 years 187 of the 200 inlays and onlays were reevaluated by a blinded examiner (D.S.). The restoration margins were visually and manually examined with a mirror and a probe (S23, Deppeler, Rolle, Switzerland) as well as proximal contacts were checked with waxed dental floss (ACT Dentalfloss, Johnson&Johnson, New Brunswick NJ, USA) and classified according to the modified United States Public Health Service (USPHS) criteria <sup>7</sup> (Table 2). In addition, tooth vitality was tested with a CO<sub>2</sub>-test and two bite-wing radiographs were taken. Inlays and onlays proving difficult to be classified, were also documented with photographs (Fig 1). Inlays and onlays that did not show any clinical changes and did not require any adjustments, were rated “Alfa”. Retorations with minor defects such as moderate overhangs or underfilled margins, or small changes in texture or color, not impairing the clinical result, were rated “Bravo”. The “Charlie” and “Delta” criteria were assigned to those inlays and onlays, requiring repairs or even replacement due to fractures, chipping or major defects. Furthermore, inlays and onlays that caused sensitivity problems, persisting pain or secondary caries, were also rated “Delta”. In order to agree on a common basis for the base-line and follow-up ratings at time of the reevaluation, the

first 10 inlays and onlays, were checked by the blinded examiner (D.S.) and the author (T.O.) in parallel. In unclear cases, the photographic and radiological documentation was used for decision-making. If there was a disagreement between clinical, radiological and photographic assessment, the worst rating was chosen. Inlays and onlays, obtaining “Alfa” or “Bravo” ratings for all criteria, were considered successful.

### **Statistical Analysis**

Based on the defined success criteria, the failure rate was calculated according to the Kaplan-Meier analysis <sup>8</sup> with the Stata 8.0 software (Stata Corporation, College Station, TX, USA). The hazard ratios for different predictors were calculated using the Cox proportional hazards model <sup>9</sup>.

### **Results**

Out of the 200 Cerec inlays and onlays originally placed in 108 patients, 89 (82%) patients with 187 (94%) inlays and onlays were available for follow-up examination up to 16 years and 11 months. Of the 187 inlays and onlays in the follow-up examination, a total of 21 (11%) inlays and onlays in 17 patients were allocated a Charlie or Delta rating, which qualified them as failures (Table 3). The failures occurred after a functional period of between 6 years, 9 months and 13 years, 10 months, whereas two teeth had to be treated endodontically after 1.5 and 2 years respectively, with the inlays remaining in situ (Table 4). One single patient presented three failures. Two patients



suffered two failures each and in 14 patients, only one inlay or onlay had to be given an insufficient rating.

Based on the Kaplan-Meier analysis for all reconstructions, the survival probability dropped to 88.7% (95% confidence interval = 0.8320 – 0.9249) after 17 years (Fig 2). 4 (5.2%) of the 77 restorations placed in premolars and 17 (15.6%) of the 109 restorations placed in molars were rated as failure. In a univariate analysis, using the proportional hazards model, the molars proved to have significantly lower survival times than premolars (hazard ratio 3.11;  $p=0.041$ ) (Fig 3). With regard to the type of reconstruction, 3-surface inlays presented a higher risk than 1-surface inlays, though it did not reach statistical significance (hazard ratio 4.19;  $p=0.167$ ) (Fig 4). 2- and 4-surface inlays and onlays did not differ from 1-surface inlays. Differentiated by gender (female / male), jaw (maxilla / mandible) or age group (<40 / >40), no significantly higher risk for failures was seen in either group. In a multivariate analysis controlling for all these variables simultaneously, the hazard ratio for molars increased to 5.05 ( $p=0.006$ ) and the one for 3-surface inlays to 8.04 with borderline statistical significance ( $p=0.052$ ), while all other effects remained clearly statistically not-significant. The most frequent reason for the 21 failures were ceramic fractures of 13 (62%) inlays and onlays and 3 (14%) fractured cusps of reconstructed teeth (technical failure). Other reasons for failures were new caries (9.5%), secondary caries (9.5%) and endodontic problems (5%) (biological failure) (Table 4).

Two of the three patients with multiple failures presented with a distinct bruxism.

The failed restorations (21) were repaired with composite (10) / ceramic (1) or replaced by new Cerec restorations (7) or PFM crowns (3) (Table 4).

## **Discussion**

Following a follow-up period of up to 17 years, 94% of the restorations were reevaluated by a blinded examiner. Although the study design did not include control groups, the low drop-out rate and the clear definition of a successful restoration permitted an accurate assessment of the technique employed. The Kaplan-Meier survival rate of 187 inlays and onlays over 17 years was 88.7%. In 11 out of the 21 inlays and onlays rated as failures, a simple repair with composite material or ceramic respectively, was possible, with the original Cerec restoration remaining in situ. Consequently, 10 (5%) of the 187 restorations had to be replaced during the 17-year observation period. Out of these, 7 teeth were reconstructed with new Cerec restorations, cutting back the hard tooth tissue only minimally. Only 3 (1.6%) of the teeth examined during the follow-up period had to be retreated using an invasive method, in these cases with a crown. This suggests that the initial defect-oriented, tooth structure saving preparation permitted a good long-term prognosis. These favorable results are similar to other reports<sup>10-12</sup> with a success probability of 84,4% after 18 years<sup>13</sup>.

It is of course not possible to compare these results to other, indirect ceramic reconstruction methods, since there are no studies available for such a period of time. However, comparison studies over five years<sup>14,15</sup> yielded similar results for various ceramic reconstruction methods, while a long-term comparison ceramic inlays made out of prefabricated Cerec Mki block-ceramic had a significantly higher survival rate than laboratory-fired ceramic inlays<sup>16,17</sup>. In addition, there are only few long-term clinical examinations for composite fillings or composite inlays, which are showing less favorable survival rates<sup>18,19</sup>.

Reported survival rate of gold cast inlays and onlays show similar results with 96.1% after 10 years and 87% after 20 years<sup>20</sup>, and a survival rate of 97% at 9 years and

90.3% at 20 years in a report also carried out by just one practitioner<sup>21</sup>. Furthermore, this direct chairside approach does not involve a laboratory stage or fee and should therefore permits more cost-effective restoration fabrication<sup>22</sup>.

Fractures of the ceramic block. accounted for 62% of the observed 21 failures. These results are compatible to other studies on Cerec inlays<sup>10-13</sup> with ceramic fractures clearly outweighing other causes of failure<sup>14,15,17</sup>. In two cases, cusp fractures were seen and in one case, a cusp suffered a fracture after an endodontic treatment of the corresponding tooth. Other authors<sup>13,16</sup> showed significantly lower survival rates of Cerec inlays because of tooth fractures in non-vital teeth. In most cases, however, the fracture occurred at the presumably thinnest region of the inlay (isthmus fracture) or at the marginal ridge (chipping) (Fig 5). This could be a hint that in such reconstructions, the minimum thickness of the ceramic, and the establishing of a proper occlusion should be respected.

The fact that three patients with multiple failures were diagnosed with bruxism, may be a hint, that this particular group of patients, should be considered a risk group with regard to Cerec restorations. This seems to be true for reconstructive materials in general<sup>23</sup>.

In two cases only, secondary caries was found at a restoration margin. There was a general, self-limiting loss of bonding composite out of the luting interface during the first year after placement<sup>24</sup>. This explains the slightly underfilled margins that could be found with a probe, but does not seem to favor the occurrence of secondary caries. That the change of the cementing gap of Cerec restorations, is not accompanied by secondary caries lesions over a long-term period was also found by other authors<sup>11,13</sup>. The consistent use of the adhesive technique for the placement of ceramic inlays and onlays

with bonding composite <sup>25</sup>, also seems to yield clinically sufficient results with the Cerec 1 method, where there are relatively large luting interfaces of up to 150  $\mu\text{m}$  <sup>24</sup> and more <sup>26</sup>.

Statistically, the failure probability was slightly higher in the 3-surface Cerec inlays, but the differences between sizes of the restorations were not significant. This supports the tooth structure saving approach, not to extend the preparation for preventive reasons. Restorations in premolars presented a significantly lower risk, than in molars. This circumstance was also found in another study <sup>13</sup>. The analyzed data did not provide any conclusive evidence as to whether this has technical reasons or whether this fact is due to better accessibility for the treatment or the patients oral hygiene.

It must be emphasized that these results were observed in a much earlier version of the system's hardware and software protocols. Furthermore, they reflected the clinical performance of only one clinician, thereby limiting the conclusions that can be drawn from this report. However, the significant improvement in the product in recent years combined with these reported experiences suggest considerable promise for the technique, which is now also more user-friendly. Evidence of improvement in the accuracy of restoration fit <sup>27</sup> and a greater variety of the possible preparation forms <sup>28</sup> also suggest better restorative prognoses. In addition to the feldspathic ceramic, different ceramic materials like leucite infiltrated glass ceramic or zirconia, were also developed <sup>29</sup>. This may possibly enhance the strength of future restorations and their esthetic outcome. New models of automated computer-aided design, like the biogeneric tooth reconstruction <sup>30</sup> may also help to reconstruct the occlusal morphology of teeth in specific clinical situations.

The results reported in this study must be assessed in the context of the caveats referred to above. The technique clearly has enormous clinical potential since it offers the

practitioner more control and ease in fabricating inlays, onlays veneers and even full ceramic crowns with very acceptable esthetics<sup>31</sup>. It has also become easier to adjust the occlusion and screen the thickness of the ceramic, which may in turn help to reduce the failure rate of the ceramic restorations.

## **Conclusion**

The clinical survival rate probability of 88.7% after 17 years according to Kaplan-Meier makes Cerec CAD/CAM restorations made of Vita Mk I feldspathic ceramic well acceptable in private practice.

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## Tables

**Table 1 Distribution of all Cerec inlays and onlays**

Type of restoration	Molars		Premolars		Canines	Total
	Upper	Lower	Upper	Lower	Upper	
<b>1-surface</b>	<b>7</b>	<b>13</b>	<b>1</b>	<b>2</b>	<b>0</b>	<b>23</b>
<b>2-surface</b>	<b>18</b>	<b>21</b>	<b>14</b>	<b>13</b>	<b>1</b>	<b>67</b>
<b>3-surface</b>	<b>20</b>	<b>20</b>	<b>38</b>	<b>7</b>	<b>0</b>	<b>85</b>
<b>≥4-surface</b>	<b>9</b>	<b>14</b>		<b>2</b> <b>0</b>	<b>0</b>	<b>25</b>
<b>Total</b>	<b>54</b>	<b>68</b>	<b>55</b>	<b>22</b>	<b>1</b>	<b>200</b>

**Table 2 Modified USPHS criteria used for rating of inlays and onlays**

### **Margin Quality (using mirror and explorer)**

Alfa:	No catches at cavity margin, but if present, overhangs and underfilled margins are invisible.
Bravo:	Probe catches at cavity margin, visible overhangs and underfilled margins, no exposed dentin or base material.
Charlie:	Probe catches at cavity margin, visible overhangs and underfilled margins, exposed dentin or base material, immobile and uncracked filling.
Delta:	Fractured or missing filling.

### **Contour (using mirror, explorer and waxed dental floss)**

Alfa:	Surface morphology correct, perhaps over-contoured, tight proximal contacts.
Bravo:	Surface morphology incorrect, perhaps under-contoured, weak proximal contacts.
Charlie:	Defective restoration, exposed dentin or base material, open proximal contacts.

### **Surface Texture (using mirror and explorer)**

Alfa:	Visually smooth surface, no tactile roughness.
Bravo:	Visible and tactile surface roughness, no pitting or craters, unpolished fissures.
Charlie:	Pitted surface or surface with craters, overall insufficient polish.

### **Color Matching (using mirror)**

Alfa:	No apparent color change, retaining shiny surface.
Bravo:	Minimal loss of translucency, but within the range of normal tooth color ( $\leq 1$ Vita - shade off).
Charlie:	Severe surface dulling, not within the range of normal tooth color ( $> 1$ Vita-shade off).

**Table 3** USPHS Ratings of Restorations at Baseline (B) and After 15 Years

USPHS criterion	Molars (n = 109)		Premolars (n = 77)		3-surface (n = 84)		2-surface (n = 66)		1-surface (n = 22)		= 4-surface (n = 15)	
	B	15 y	B	15 y	B	15 y	B	15 y	B	15 y	B	15 y
Margin quality												
Alpha	90	21	66	16	72	15	57	9	19	8	11	2
Bravo	19	80	11	57	12	60	9	55	3	12	4	13
Charlie	0	2	0	0	0	1	0	1	0	0	0	0
Delta	0	6	0	4	0	8	0	1	0	2	0	0
Contour												
Alpha	68	45	45	31	51	30	38	30	16	13	8	6
Bravo	41	57	32	45	33	51	28	33	6	9	7	8
Charlie	0	7	0	1	0	3	0	3	0	0	0	1
Surface texture												
Alpha	80	31	54	21	61	24	50	20	15	10	11	4
Bravo	29	77	23	56	23	59	16	46	7	12	4	11
Charlie	0	1	0	0	0	1	0	0	0	0	0	0
Color matching												
Alpha	82	66	59	45	65	50	51	39	17	15	11	8
Bravo	27	43	18	32	19	34	15	27	5	7	4	7
Charlie	0	0	0	0	0	0	0	0	0	0	0	0

**Table 4** Details about the 21 failing restorations

Restoration	Time in function	Reason of failure (technical T / biological B)		Consequences of failure
#1	6y 9m	ceramic fracture	T	new Cerec
#2	7y 5m	ceramic fracture	T	repair with composite
#3	7y 6m	ceramic fracture	T	repair with composite
#4	7y 7m	tooth fracture	B	crown
#5	7y 8m	ceramic fracture	T	repair with composite
#6	8y 3m	ceramic fracture	T	repair with composite
#7	8y 5m	tooth fracture	B	crown
#8	8y 8m	tooth fracture	B	crown
		endodontics 1y5m		
#9	8y 10m	ceramic fracture	T	new Cerec
#10	8y 10m	new caries	B	composite filling
#11	8y 11m	ceramic fracture	T	new Cerec
#12	8y 11m	ceramic fracture	T	repair with composite
#13	9y	ceramic fracture	T	new Cerec
#14	9y 2m	ceramic fracture	T	new Cerec
#15	9y 8m	marginal caries	T	new Cerec
#16	9y 9m	new caries	B	composite filling
#17	10y 4m	ceramic fracture	T	repair with composite
#18	10y 7m	endodontics 2y1m	B	small Cerec within restoration (still in use)
#19	13y 6m	marginal caries	B	new Cerec
#20	13y 8m	ceramic fracture	T	repair with composite
#21	13y 10m	ceramic fracture	T	repair with composite

## Figures



Fig. 1a



Fig. 1b

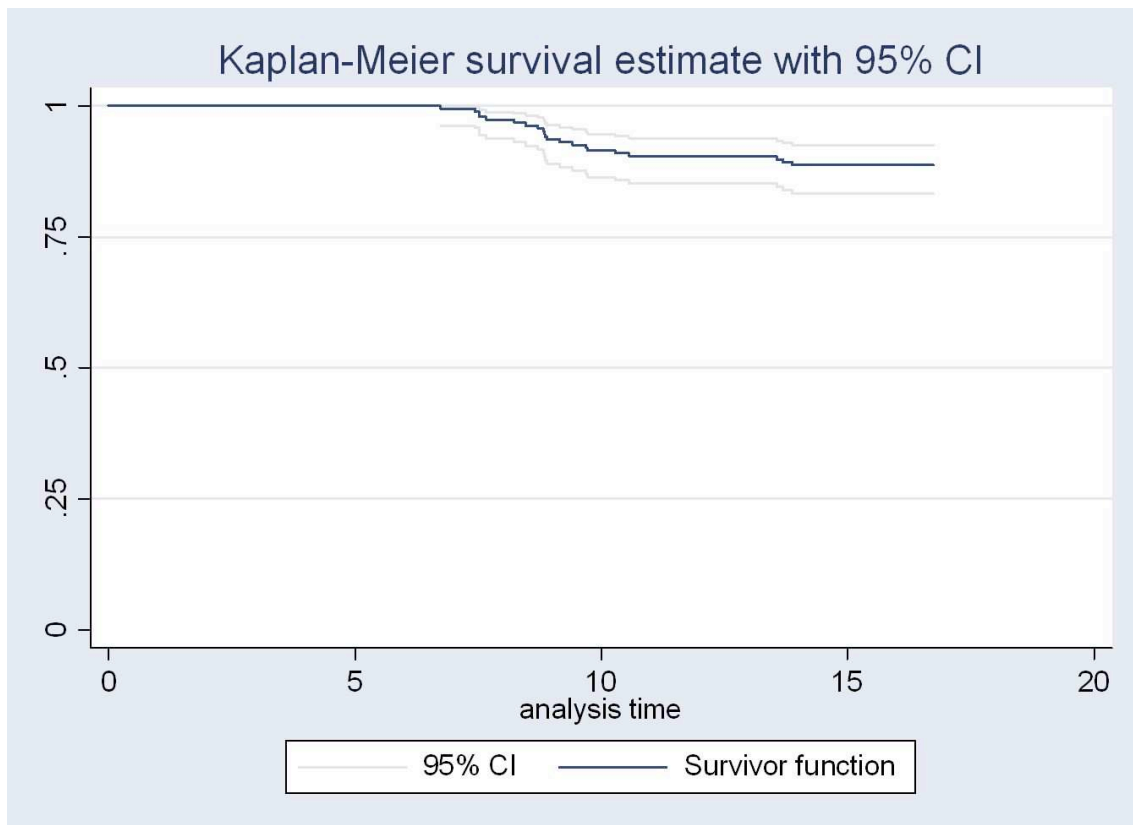


Fig. 2

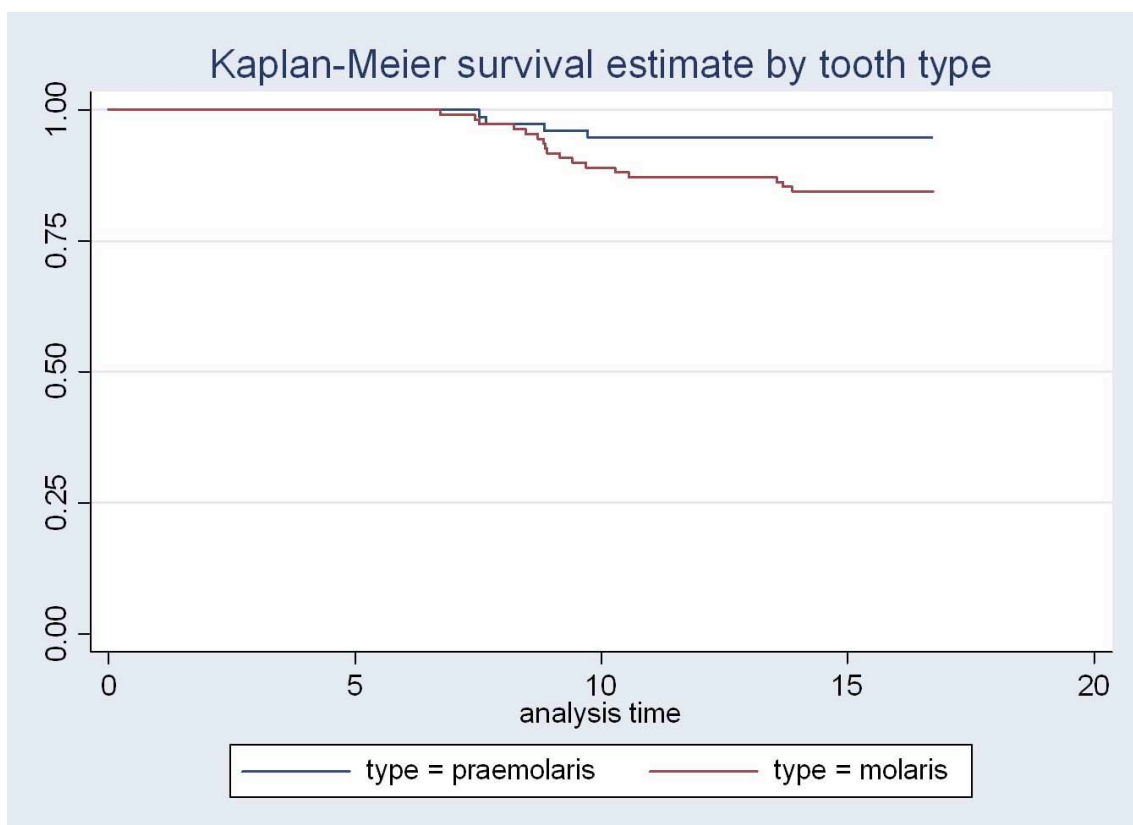


Fig. 3

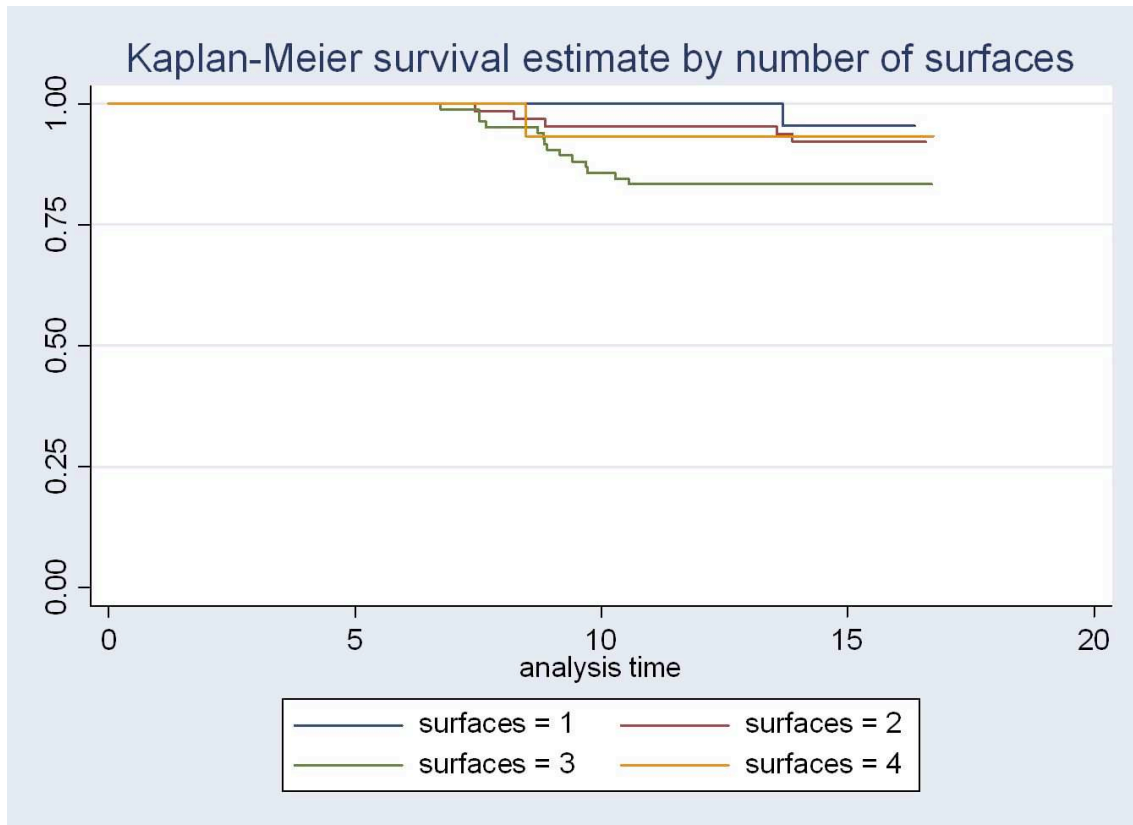


Fig. 4



Fig. 5a





Fig. 5b